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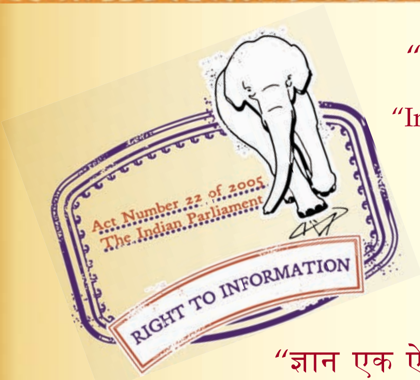
Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS 11772 (2009): Design of drainage arrangements of energy dissipators and training walls of spillways - Guidelines [WRD 9: Dams and Spillways]



"ज्ञान से एक नये भारत का निर्माण"
Satyanarayan Gangaram Pitroda
"Invent a New India Using Knowledge"

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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भारतीय मानक

स्पिलवेज से ऊर्जा अवशोषकों एवं ट्रेनिंग वॉल की निकास व्यवस्थाओं के डिजाइन — मार्गनिर्देश

(पहला पुनरीक्षण)

Indian Standard

DESIGN OF DRAINAGE ARRANGEMENTS OF ENERGY DISSIPATORS AND TRAINING WALLS OF SPILLWAYS — GUIDELINES

(First Revision)

ICS 93.16

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 2009

Price Group 7

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Dams and Spillways Sectional Committee had been approved by the Water Resources Division Council.

Energy dissipators for dams involve problems of erosion of foundation material on their downstream side and occurrence of excess seepage under them. The complexity of these problems depends upon type, stratification, permeability, homogeneity and other characteristics of the foundation material as well as size and physical requirements of the energy dissipators.

The probable hydrostatic uplift forees, under adverse conditions, on the energy dissipators partially relieved by their drainage system, shall be estimated conservatively considering characteristics of their foundations and drainage systems.

The critical condition may be channel empty after rapid closure of gates of a gated spillway or dropping of reservoir level to crest of an ungated spillway with water in foundations at maximum gradient under applicable reservoir conditions, or water flowing from a spillway under design flood.

This standard was first published in 1986. This revision is being taken up in order to incorporate the knowledge gained during the use of this standard. The main changes incorporated in this revision are as under:

In Fig. 4, the inlet of the drainage outlet on the face of the spillway was shown preceded with one eyebrow. This presence of the eyebrow on the surface of the high velocity flow at the toe of the spillway was observed to be highly objectionable as it may lead to cavitation damage. Therefore in this revision suitable modifications have been made in **3.2.4** and Fig. 4.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the results of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

DESIGN OF DRAINAGE ARRANGEMENTS OF ENERGY DISSIPATORS AND TRAINING WALLS OF SPILLWAYS — GUIDELINES

(First Revision)

1 SCOPE

1.1 This standard covers guidelines for drainage aspects of energy dissipators and training walls of spillways.

1.2 Various energy dissipators covered are:

a) Buckets — roller (solid and slotted, and ski-jump type); and
b) Stilling basins — sloping and horizontal aprons.

1.3 Drainage aspects of chutes have been covered in IS 5186.

2 REFERENCE

The following standard contains provisions, which through reference in this text, constitutes provision of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below:

IS No.	*Title*
5186 : 1994	Design of chute and side channel spillways — Criteria (*first revision*)

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Drainage — Safe removal of excess seepage water below an energy dissipation structure, or from behind a training wall.

3.2 Filter — A layer or a combination of layers of graded pervious materials designed and placed in such a manner as to provide drainage and yet prevent the movement of soil particles with seepage water.

3.3 Uplift Pressure — The upward hydraulic pressure in the pores of a body (pore or interstitial pressure) or on the base of an energy dissipator or a training wall.

4 DRAINAGE ASPECTS FOR ENERGY DISSIPATORS

4.1 Uplift Forces, Dynamic Pressures and Drainage

4.1.1 Due to reservoir upstream of a dam and tailwater downstream, uplift pressures besides occurring as internal pressures in pores, cracks and seams of dam foundations and in the body of the dam also occur under its energy dissipators.

4.1.2 The pore spaces in foundation material below the energy dissipators get filled with water which exerts pressures in all directions. Such pressures depend upon head of water in the reservoir and also on tailwater head. Phenomena like micro turbulence due to high velocity flows over panelled dissipator or flows or earthquakes may also affect the uplift pressures.

4.1.3 With proper care, uplift pressures on the energy dissipators can be minimized by providing weep holes, surface drains, drainage holes in foundation rock and providing relief wells in pervious foundations.

4.1.4 In case of energy dissipators, weight of concrete floor and anchorage to the rock, if provided, shall be designed to withstand uplift and dynamic pressures with ample factor of safety to take care of limitations in accurate evaluation of such pressures.

4.1.5 Liberal allowances shall be made for maximum probable uplift pressures and quantity of seepage water for foundation material under the most adverse headwater, tailwater, with or without groundwater conditions for design of drainage systems for the energy dissipators with an ample factor of safety.

4.1.6 Drainage aspects of buckets, either roller or ski-jump type and stilling basins shall be essentially similar but shall be governed by tailwater heads and types of their foundation strata.

4.1.7 For a properly designed dam, a well planned curtain grouting programme is normally envisaged for its foundation. Although such well planned grouting programme may materially reduce seepage through the foundation, some means shall be provided to intercept water which may percolate through and around the grout curtain and which, if not removed, may build high hydrostatic pressures on its energy dissipator.

4.1.8 Drainage is provided under floor slabs of energy dissipators to reduce uplift pressures. Effective drainage, below the energy dissipators generally limits uplift pressures to required design limits. The degree

of effectiveness of the drainage systems depends upon characteristics of foundation material and dependability of their effective maintenance.

4.1.9 Sometimes, under the special conditions referred to in **4.4.1**, drainage galleries, sumps, etc, may be provided below the energy dissipators of large dams, if considered necessary.

4.2 Drainage Holes and Drains for Energy Dissipators

4.2.1 Common schemes for drainage of foundation material below floor slabs of the energy dissipators are:

a) Providing vertical formed holes or pipes through floor slabs (this is the simplest scheme and may be used for minor works) (*see* Fig. 1),
b) A grid of half round pipe drains or tile drains along the foundation surface (may be adequate for low heads) (*see* Fig. 2),
c) Drain holes drilled into the foundation rock or relief wells into pervious foundation material in combination with formed holes or pipes through floor slabs (preferable for higher heads and sound formation) (*see* Fig. 3), and
d) An elaborate system for large major projects as described in **4.4**.

4.2.2 Formed holes or pipes for relief of uplift pressure are provided through the floor slabs. Their spacing may vary from 2 to 5 m in both directions (*see* Fig. 1).

4.2.3 The grid of half round drains shall follow the alignment of vertical or inclined drain holes, if provided, to facilitate collection and disposal of percolating water from them. The grid of half round drains shall be of minimum 200 mm diameter, leading water to relatively larger diameter collector half round drains or galleries/sumps near the upstream and/or downstream ends of the energy dissipators and/or near the training walls.

4.2.4 Large diameter collector half round drains near upstream and/or downstream ends of the energy dissipators and/or near the training walls at both their ends shall be connected to outlets. These drains release water either by pressure or by gravity flow through outlets provided on the downstream of energy dissipators and/or sides of the training walls as indicated (*see* Fig. 4). The outlets provided to discharge the water collected into the half round drains shall be provided with non-return valves flush with the exit surface.

4.2.5 The grid of half round drains and/or large diameter collector half round drains shall be alternatively connected with galleries below the energy dissipators to lead water into sumps or directly into sumps generally provided below the energy dissipators and/or on backsides of the end training walls. Water is pumped out from sumps for its disposal from suitable locations above the maximum tailwater level.

4.2.6 Each collector drain shall have at least two or preferably more outlets so that all drains may function satisfactorily even if some outlets get choked up (*see* Fig. 4).

4.2.7 The half round drains may either be vitreous clay or plain concrete pipes and shall be laid in graded material which acts as filter, or on sub-grade as recommended in **3.3.1**.

4.2.8 The drains holes are usually NX holes (75 mm diameter). They shall be drilled after completion of the foundation grouting in their vicinity, if any, to avoid their clogging.

4.2.9 The vertical drain holes shall be adopted where joints and stratification in foundation rock have complex or dominantly horizontal pattern. The inclined drain holes shall be adopted where joints and stratifications in foundation rock have dominantly inclined pattern.

4.2.10 The spacing of drain holes may vary from 3 to 10 m in both directions and their depth may vary from 20 to 40 percent of tailwater depth when no other supporting data is available. The spacing shall be closer for rocks having low permeability.

4.2.11 In case detailed studies about joints and stratification in foundation rocks, their permeability and anticipated quantity of seepage from them have been made, the depth of vertical or inclined drain holes shall be based on such studies. These holes shall be connected to a grid of half round drains and/or drains in galleries under the energy dissipators.

4.2.12 The horizontal drain holes shall be preferred where joints and stratification in foundation rock have a dominantly vertical pattern. The horizontal drain holes shall be drilled into foundation rock from the gallery either perpendicular to its alignment or in a fan shape with a gentle slope towards the gallery for easy disposal of percolating water. The depth of such holes may be up to 20 m or more depending on ease of drilling and subsequent maintenance for their effective functioning (*see* Fig. 5).

4.3 Sub-grade and Outlets for Drains

4.3.1 The sub-grade under half round pipe drains shall consist of porous concrete pad laid to required grades, wherever necessary, on foundation rock to receive half round vitreous clay pipes/plain concrete pipes.

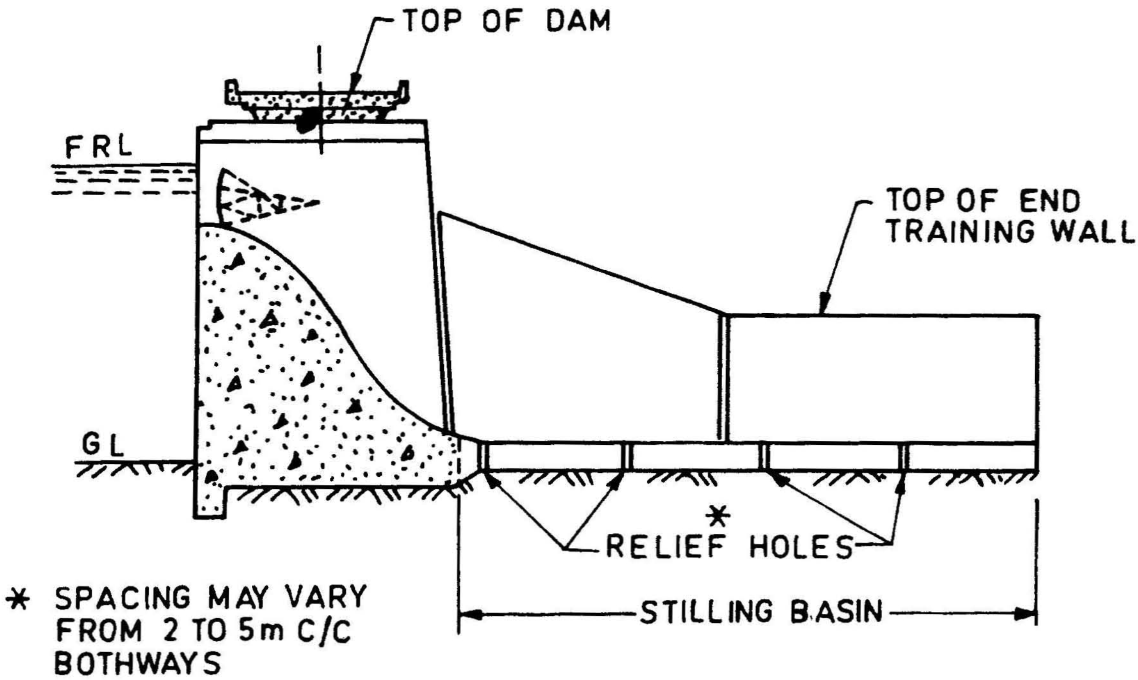


FIG. 1 RELIEF HOLES IN THE APRON FLOOR

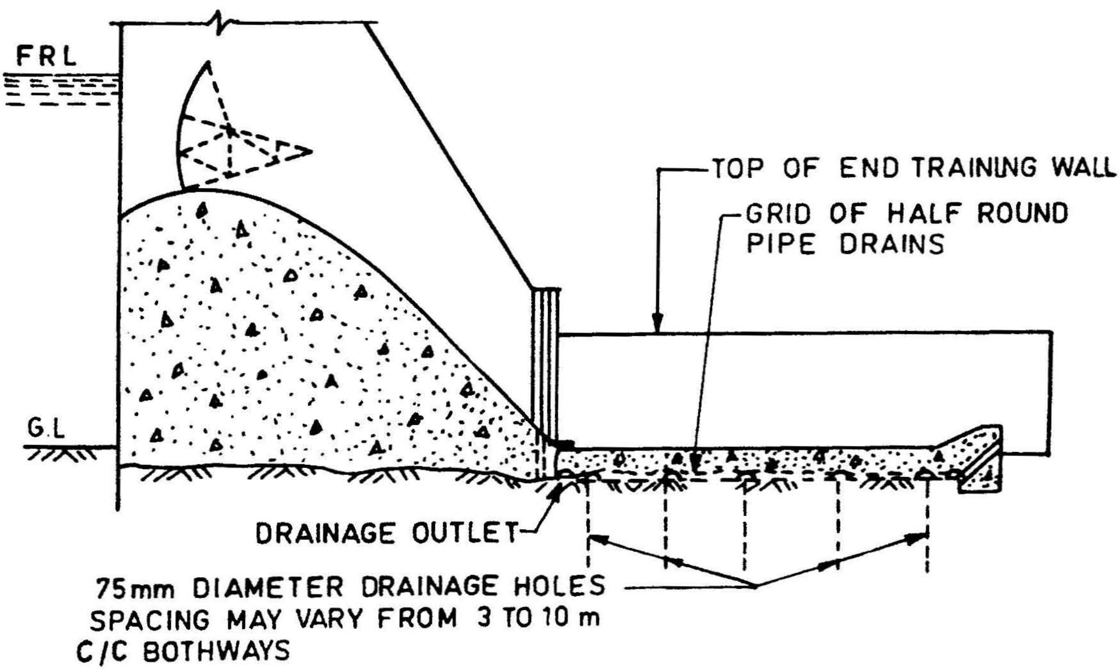


FIG. 2 DRAINAGE HOLES DRILLED INTO THE ROCK

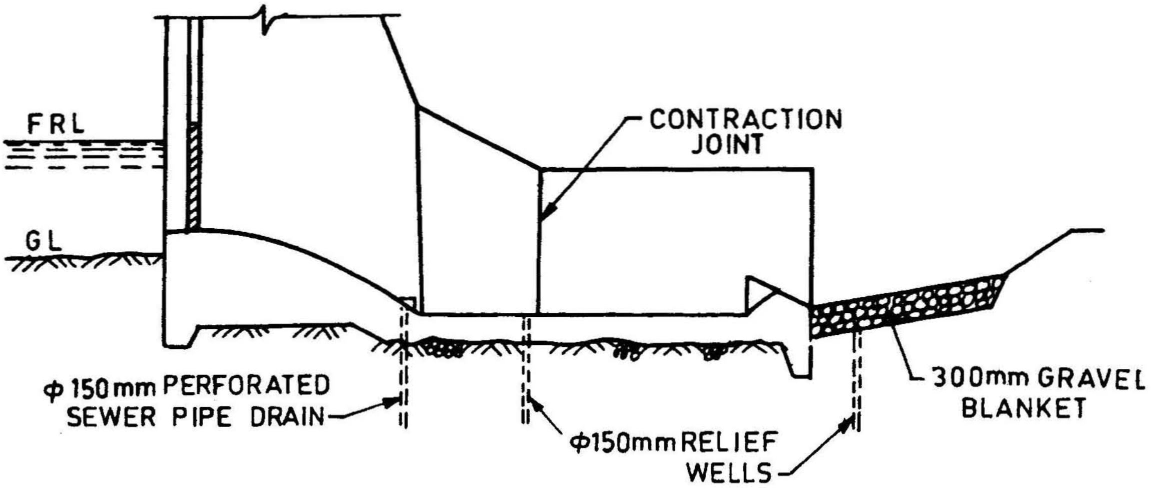


FIG. 3 RELIEF WELLS IN PERVIOUS FOUNDATIONS

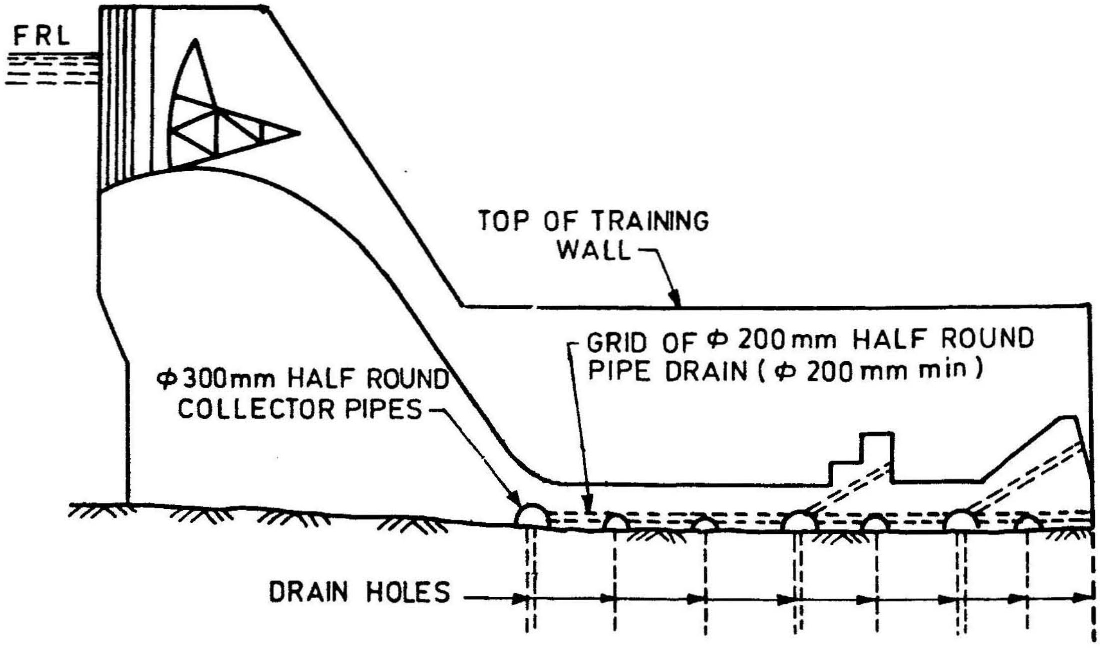


FIG. 4 DRAINAGE OUTLETS IN STILLING BASIN

4.3.2 The half round pipes may be directly placed on foundation rock wherever feasible. The porous concrete may be used under the half round pipes for maintaining proper connections among them and maintaining their levels and grades.

4.3.3 Different alternative arrangements for laying the half round drains are shown in Fig. 6A, 6B and 6C.

4.3.4 Gravel blankets, wherever provided, shall be well graded to prevent movement of foundation material with flow of seepage water.

4.3.5 Seepage water collected in drains below the energy dissipators may be disposed of by one or more of the following common methods:

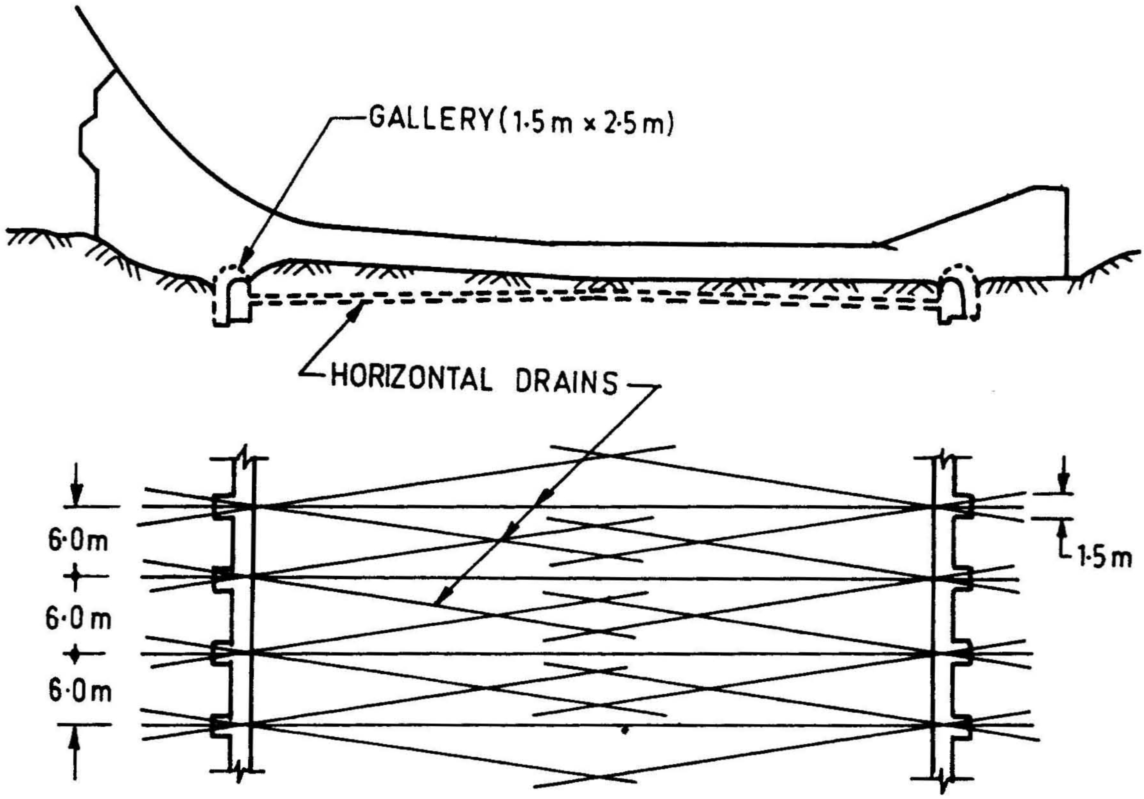
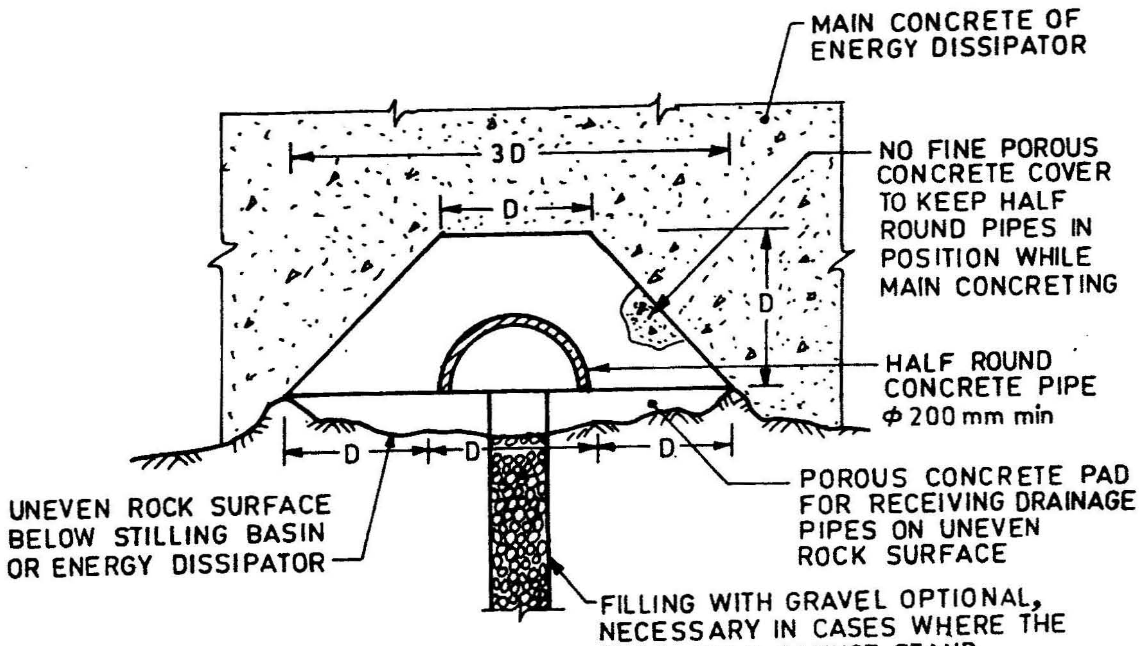
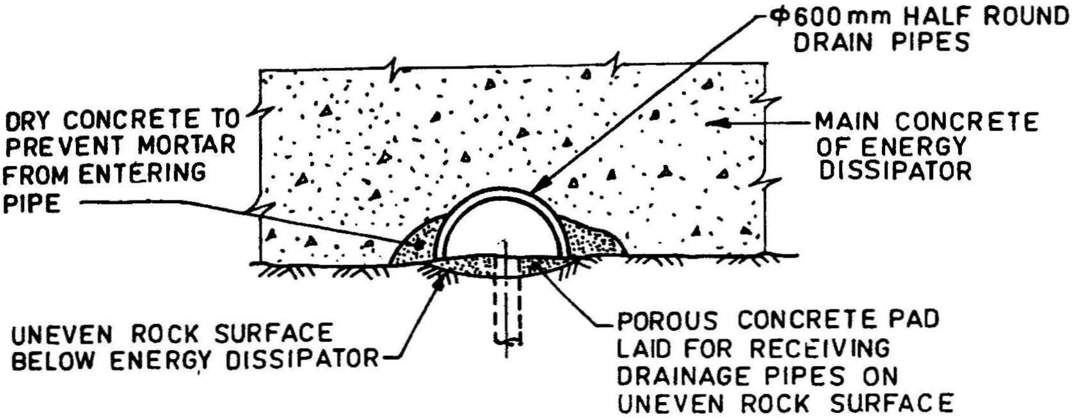


FIG. 5 TYPICAL SCHEME SHOWING HORIZONTAL DRAINS

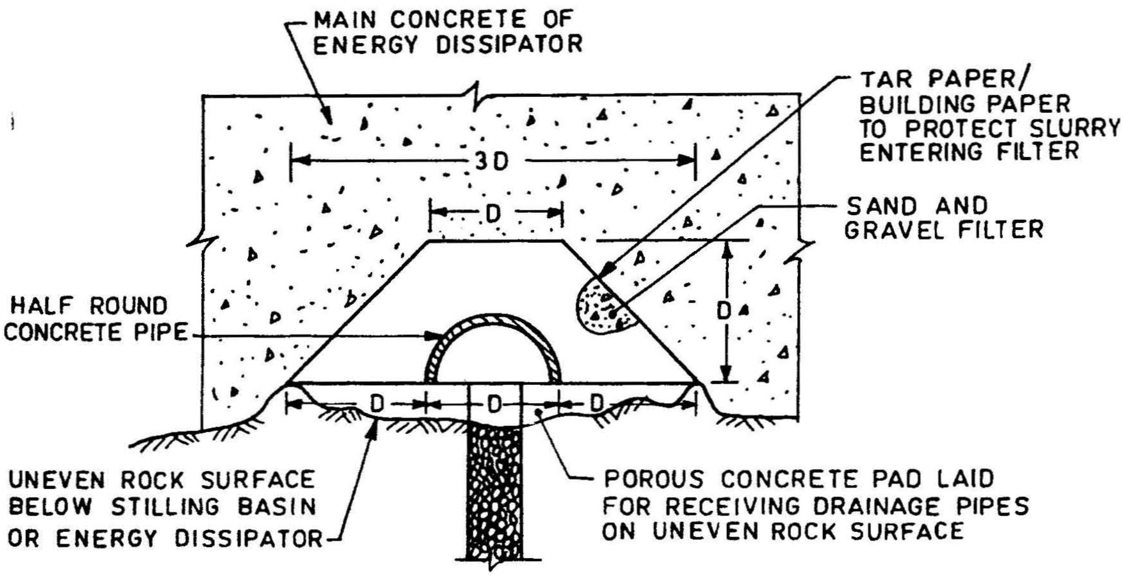


6A Details for Laying of Half Round Pipe Drains (Alternative Arrangement 1)

FIG. 6 HALF ROUND PIPE DRAINS — *Continued*



6B Details for Laying of Half Round Pipe Drains (Alternative Arrangement 2)



6C Details for Laying of Half Round Pipe Drains (Alternative Arrangement 3)

NOTES

1 Half round pipe drains shall be placed directly on rock wherever possible.

2 Porous concrete shall be used under pipes wherever necessary so as to maintain proper grade and connection of pipe.

FIG. 6 HALF ROUND PIPE DRAINS

a) Outlets discharging seepage water by gravity:

1) Outlets through dentated sills for stilling basins (*see* Fig. 4),

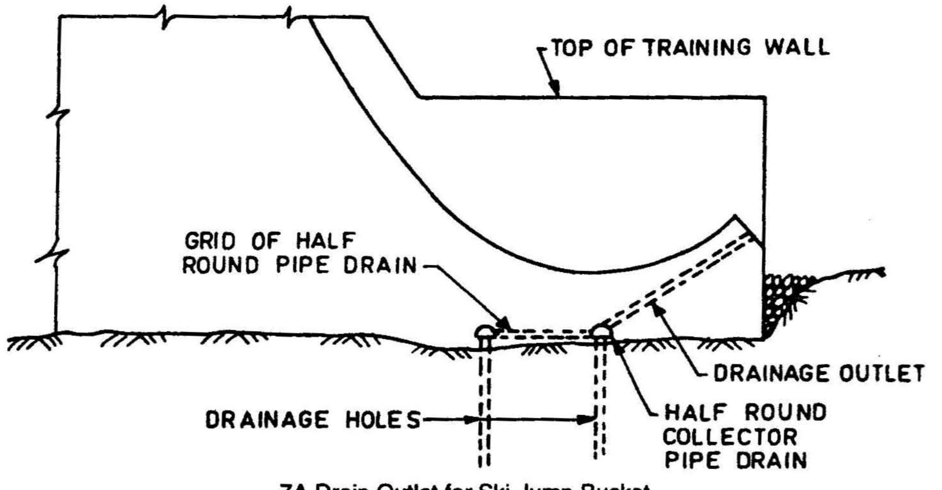
2) Outlets from downstream face of sill of ski-jump bucket (*see* Fig. 7A),

3) Outlets from downstream face of sill of slotted roller bucket (*see* Fig. 7B),

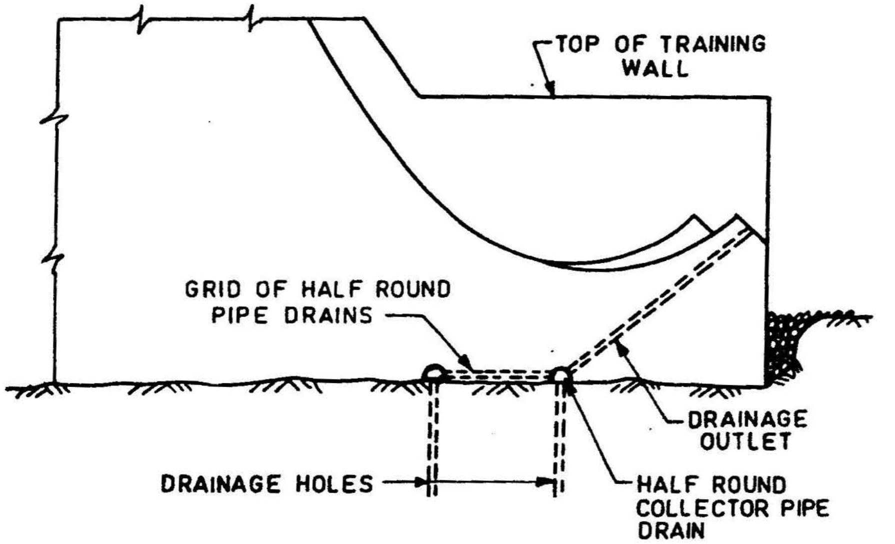
4) Outlets from downstream face of sill of solid roller bucket (*see* Fig. 7C), and

b) Outlets discharging seepage water by pumping from sumps provided below the stilling basins/buckets and/or behind the end training walls.

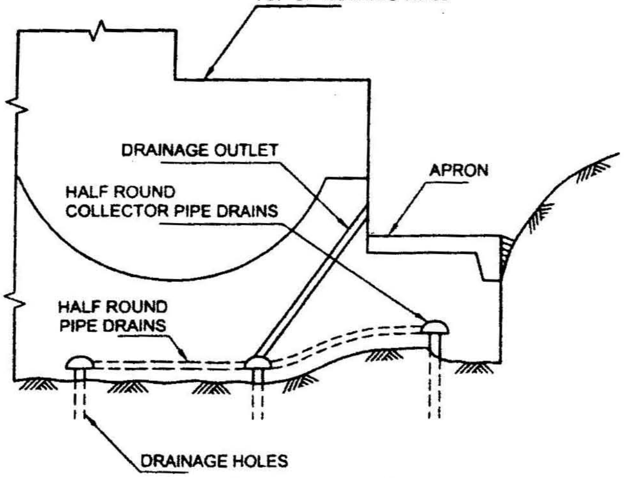
4.3.6 A typical scheme illustrating the drainage arrangement of half round pipes below a stilling basin and behind a training wall, having outlets discharging into the stilling basin is shown in Fig. 8A, 8B and 8C.



7A Drain Outlet for Ski-Jump Bucket

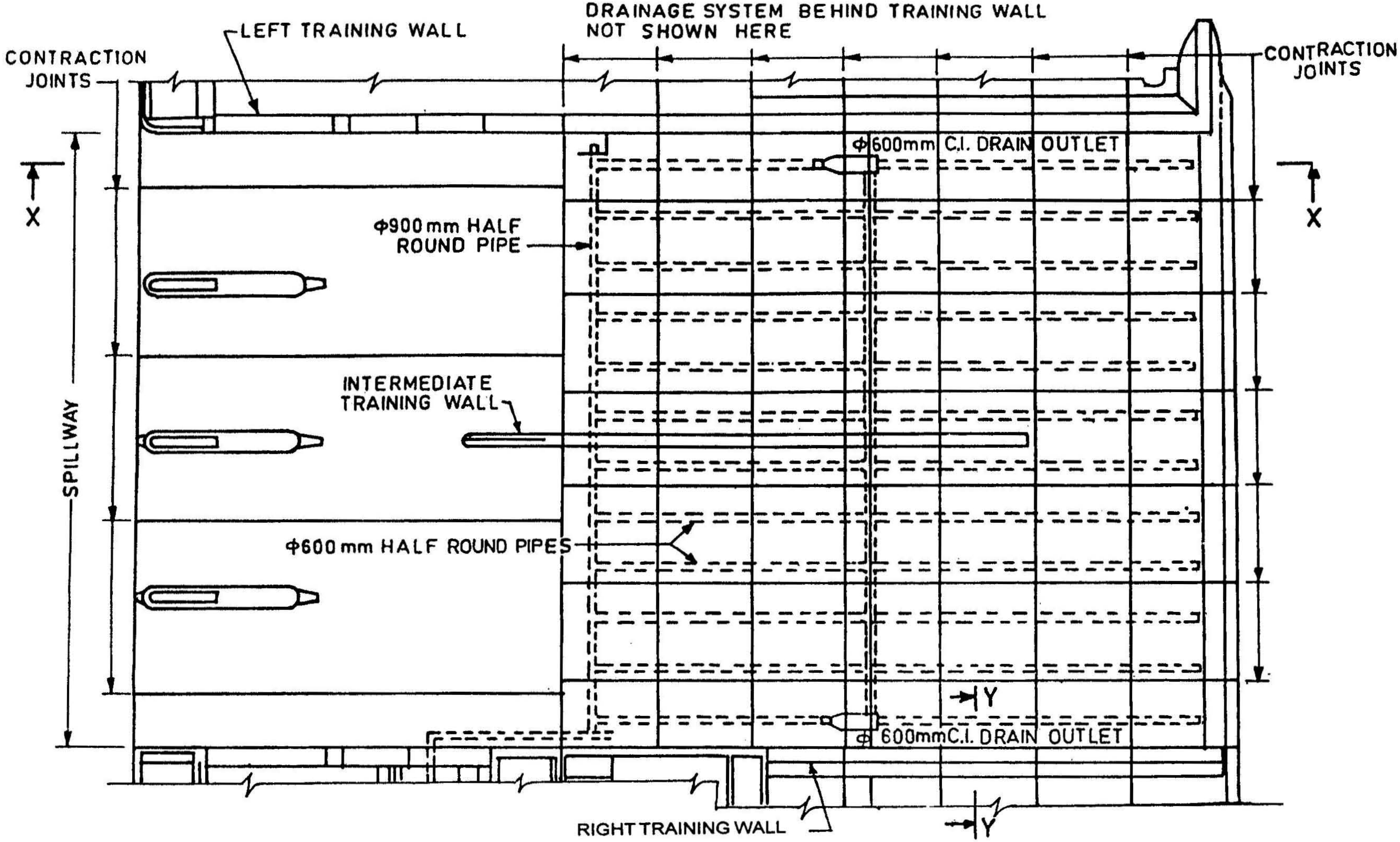


7B Drain Outlet for Slotted Roller Bucket



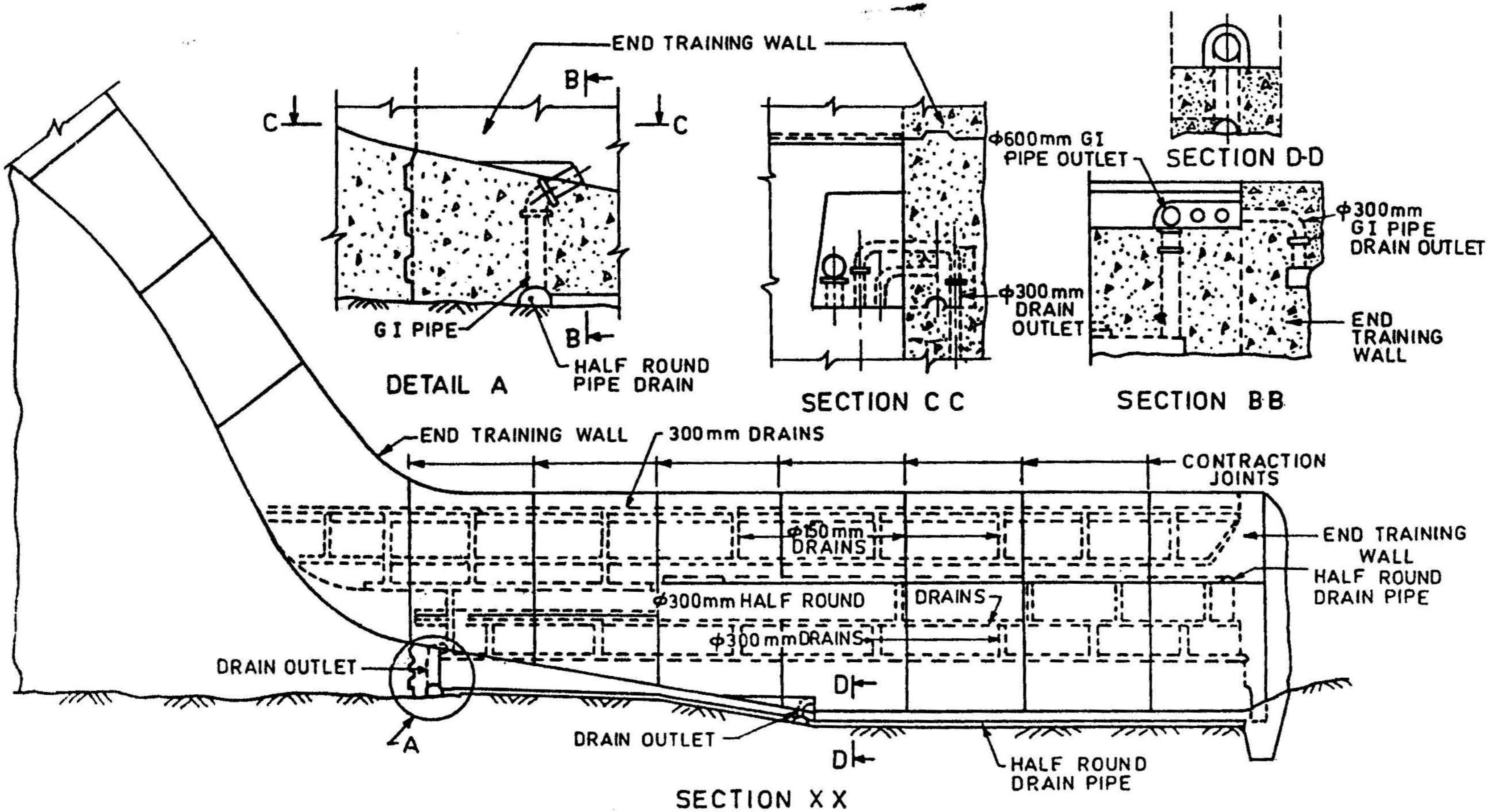
7C Drainage Holes in Solid Roller Bucket

FIG. 7 DRAIN OUTLET FOR BUCKETS



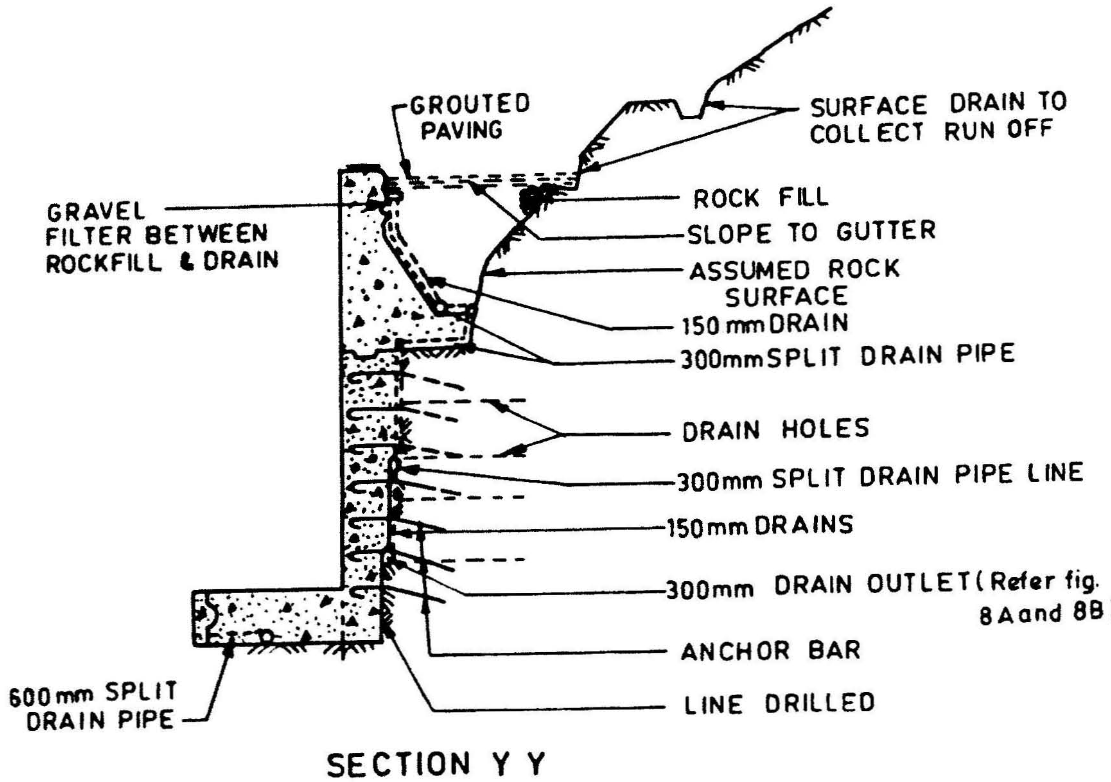
8A Plan

FIG. 8 A TYPICAL SCHEME ILLUSTRATING DRAINAGE ARRANGEMENTS BELOW STILLING BASINS — *Continued*



8B Section XX

FIG. 8 A TYPICAL SCHEME ILLUSTRATING DRAINAGE ARRANGEMENTS BELOW STILLING BASINS — *Continued*



8C Section Y Y

FIG. 8 A TYPICAL SCHEME ILLUSTRATING DRAINAGE ARRANGEMENTS BELOW STILLING BASINS

4.3.7 For large stilling basins or buckets having operating heads higher than 50 m or velocities greater than 30 m/s, it is not desirable to provide outlets of drains through the stilling basins/buckets, floorslabs and training walls discharging into the basins/buckets as their projections may trigger cavitations. This is also brought out in **4.4**.

4.4 Drainage Arrangement for Special Conditions

4.4.1 Under the special conditions involving large reservoir heads and/or large spillway discharge and/ or large tailwater level fluctuations, it may be desirable to design more elaborate drainage system to minimize uplift pressures on the floor of the energy dissipator.

4.4.2 Thorough investigations of foundation conditions and liberal allowances for uncertainties are necessary for the design of such a drainage system under the energy dissipator.

4.4.3 For ensuring satisfactory long term performance leading to uplift pressures within limits considered in the design for energy dissipators involving special conditions, the recommendations given in **4.4.3.1** to **4.4.3.7** shall be considered in addition to providing the drainage system in accordance with **4.3.5**.

4.4.3.1 A drainage gallery (with the same cross-section as that of the dam galleries) shall be provided around full periphery of the stilling basin or the bucket. The floor level of the drainage gallery shall be about 1 to 1.5 m below the drains under the energy dissipator. The segments of the peripheral gallery which are parallel to the end training walls may be located behind them.

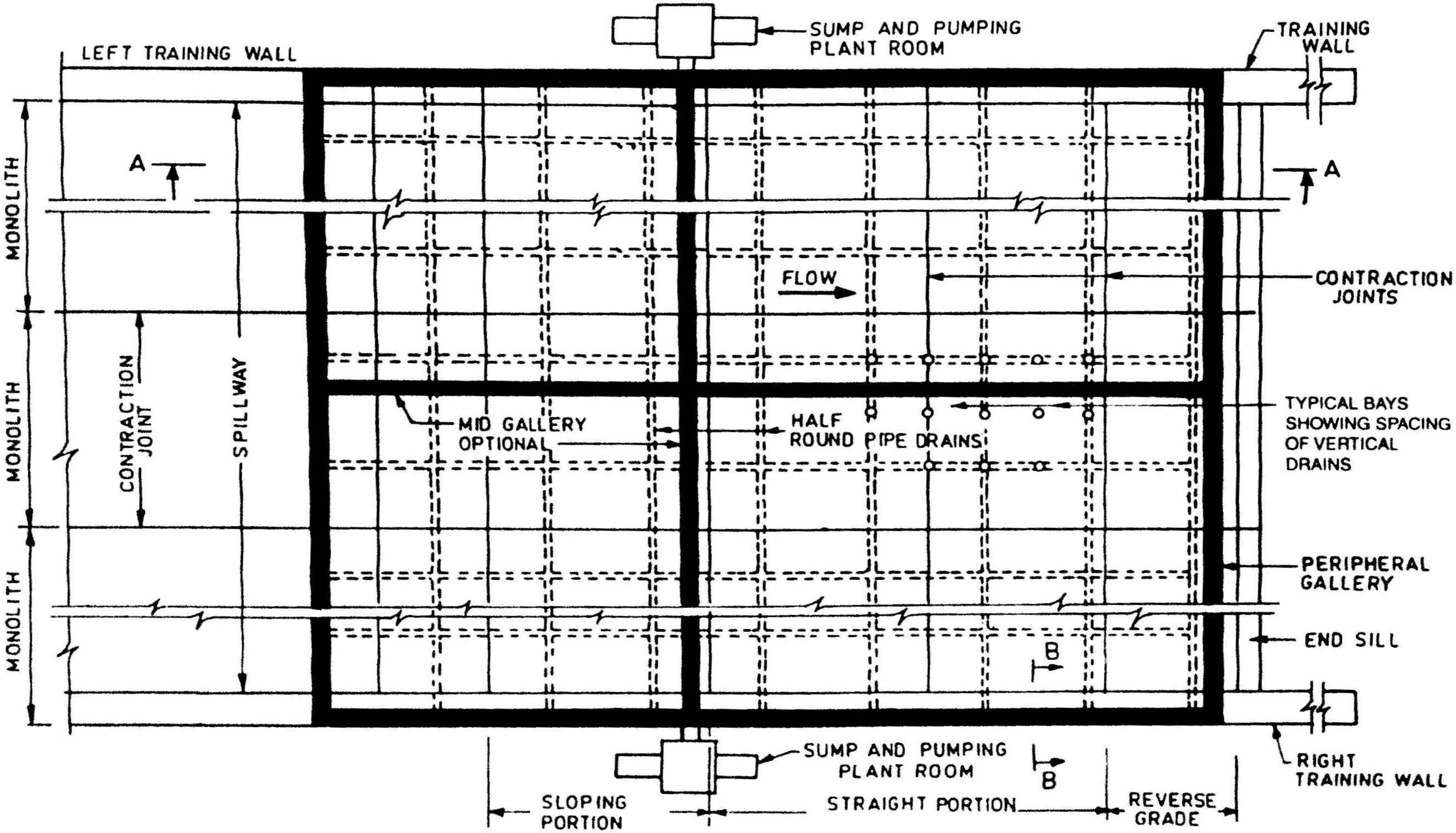
4.4.3.2 Additional intermediate galleries either in longitudinal direction or in transverse direction shall be provided if dimensions of the energy dissipator are too large (*see* Fig. 9).

4.4.3.3 Pipes shall be provided for drilling holes for grouting and drainage from the galleries, if uplift pressures remain excessive even after providing arrangements recommended in **4.4.3.1** and **4.4.3.2**.

4.4.3.4 Adequate provision of sumps below floors of the galleries for collecting seepage water, and of shafts for connecting the sumps/galleries with outlets shall be made for providing access and facility for installation of pipes for pumping out water.

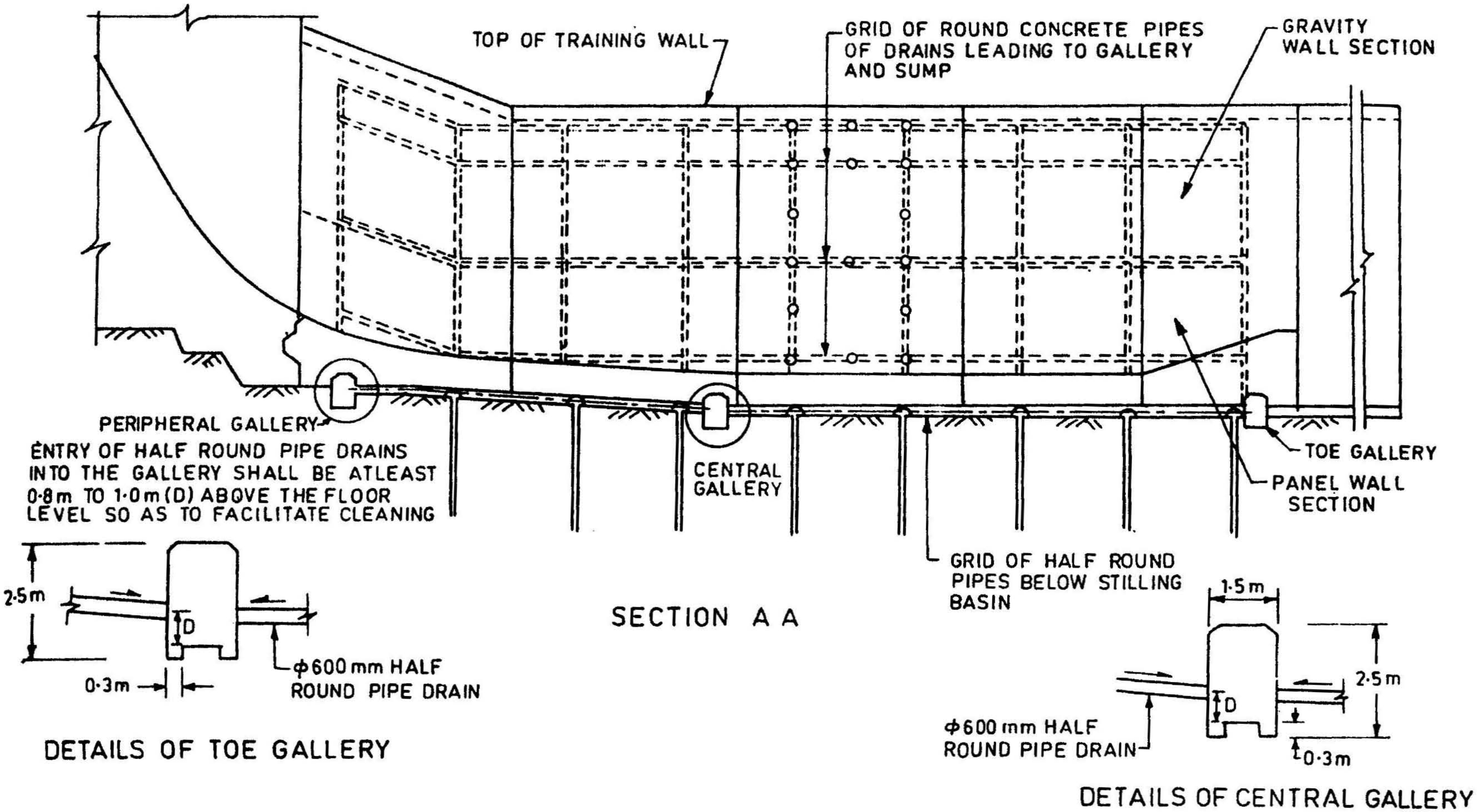
4.4.3.5 Necessary arrangement shall be made for an effective ventilation system for peripheral gallery.

4.4.3.6 The pumping plant shall be in the form of at



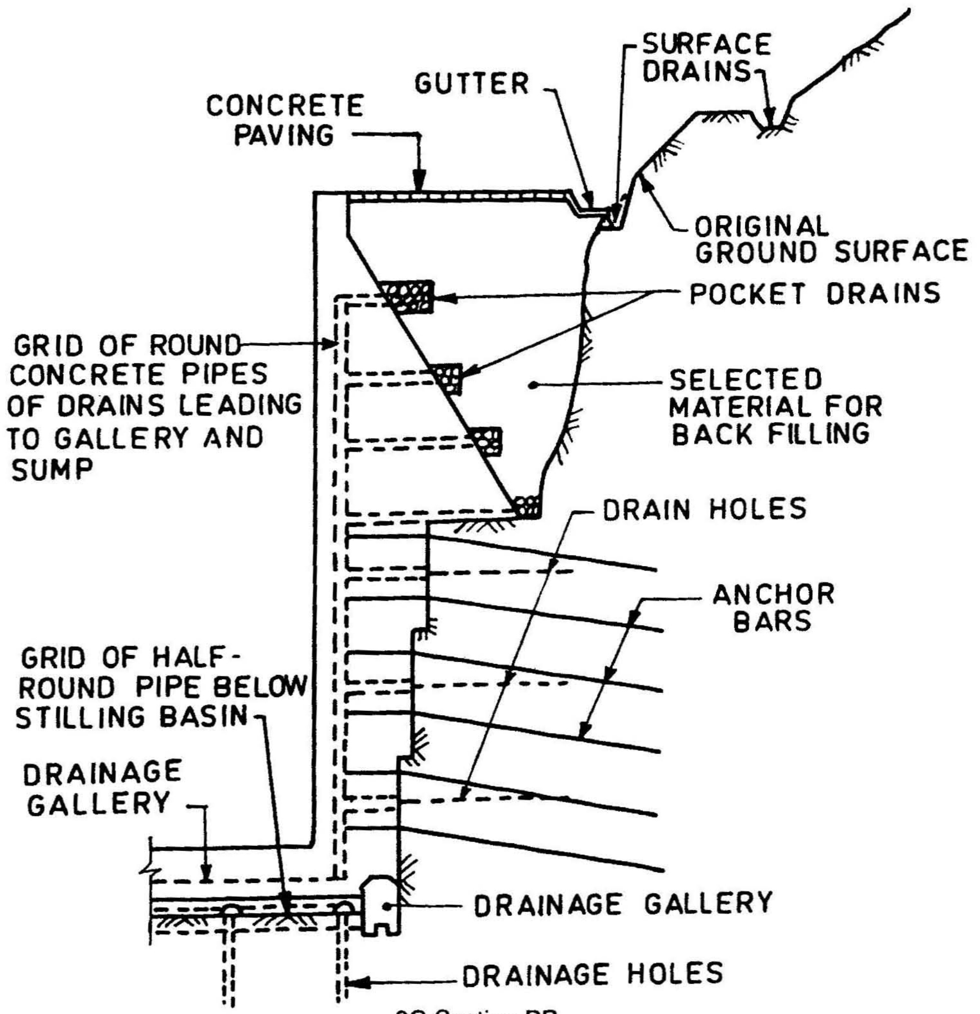
9A Plan

FIG. 9 BROAD OUTLINE OF A TYPICAL GALLERY SYSTEM FOR A MAJOR PROJECT — *Continued*



9B Longitudinal Section

FIG. 9 BROAD OUTLINE OF A TYPICAL GALLERY SYSTEM FOR A MAJOR PROJECT — *Continued*



9C Section BB

NOTE — The drain discharge from under the energy dissipator and behind the training wall is collected into the gallery and finally into the sump from where it is pumped out.

FIG. 9 BROAD OUTLINE OF A TYPICAL GALLERY SYSTEM FOR A MAJOR PROJECT

least two pump units at each location for disposing of seepage water. It shall have an overall factor for safety of at least four in terms of capacity of pumping.

4.4.3.7 An independent access shall be provided for the galleries below the floor of the energy dissipator.

4.4.4 A broad outline of a typical gallery system suitable for a large energy dissipator is shown in Fig. 9.

4.5 Surface Drainage for Energy Dissipators

4.5.1 Sumps with streamlined profiles may be provided close to training walls in low-velocity area in stilling basins/buckets to facilitate their dewatering for inspection and maintenance.

4.5.2 Where practicable, drain pipes may be provided to dispose of standing water and to reduce pumping costs during inspection.

5 DRAINAGE ASPECTS OF TRAINING WALLS

5.1 General

Training walls of the following types are generally provided with energy dissipators:

a) Gravity/cantilever walls, and
b) Anchored training walls.

5.1.1 Hydrostatic forces may develop on the training walls of energy dissipators due to accumulation of seepage water behind them.

5.1.2 Suitable drainage arrangements shall be provided to control or minimize saturation of backfill material and to reduce hydrostatic forces on the training walls. They shall be designed with liberal dimensions and suitable provisions against clogging.

5.2 Gravity or Cantilever Training Walls

5.2.1 Drainage behind the training walls may be effected by providing either permeable backfill, pockets, channels in two directions, a continuous blanket, inclined drains, enveloping drains, etc, using freely draining well-graded material.

5.2.2 The conveying units to dispose of seepage water from backsides of the training walls may either be weep holes or longitudinal perforated vitreous clay or corrugated galvanized steel sheet pipe drains. The weep holes through the walls may convey the water collected from different arrangements behind the walls as mentioned in **5.2.3** and discharge it in front. The longitudinal drains may convey water to the point from where it may be disposed of by gravity flow or may convey it to sumps from which it may be pumped to points from where it may be disposed of by gravity flow.

5.2.3 The commonly adopted types of drainage arrangements for the training walls are illustrated in Fig. 10. In cases where outlets are provided to discharge into stilling basins/buckets, they may be provided with non-return valves:

a) A simple system may consist of weep holes through the training walls (*see* Fig. 10A). The weep holes may consist of either vitreous clay pipes/concrete pipes/GI pipes, 100 mm or more in diameter. Their spacing may vary from 1.5 to 5.0 m in both directions. This system is suitable for backfill consisting of permeable material which drains freely. At the entry to each weep hole, a grill protected by a suitable filter shall be provided to prevent the weep hole from getting clogged up.

b) For backfill which is not sufficiently permeable, pockets of coarse material may be placed around the end of each weep hole to facilitate drainage (see Fig. 10B). A more elaborate arrangement may provide continuous horizontal channel of coarse material, along inner ends of weep holes supplemented by vertical channels (0.3 m × 0.3 m square section) placed midway between the weep holes, with their lower ends joining the horizontal channel (*see* Fig. 10C). To further increase effectiveness, the entire backside of a training wall may be covered with 300 mm thick gravel blanket (*see* Fig. 10D).

c) An inclined drain provided is relatively more effective as it reduces both earth pressure and seepage (*see* Fig. 10E).

d) For a backfill of expansive soils, an envelope drain may be provided (*see* Fig. 10F). This system minimizes changes in moisture content in the backfill.

5.2.4 The drainage system behind the training walls shall not create a short seepage path to the downstream side of the main control section.

5.3 Drainage Arrangements for Special Conditions

For training walls of large stilling basins or buckets having operating heads higher than 50 m or velocities greater than 30 m/s, outlets of weep holes shall not be provided projecting on inside face of the training walls as their projections may trigger cavitation. In such cases, the drainage arrangements for training walls may be integrated with the drainage arrangements of the stilling basins/buckets or the outlets which convey water to galleries/sumps from where it may be pumped out (*see* Fig. 9C).

5.4 Anchored Training Walls

5.4.1 For concrete/masonry anchored training walls, adequate drilled holes shall be provided in the rock behind them to drain seepage water and to relieve hydrostatic pressures that may develop due to saturation.

5.4.2 If the drain holes are not used, transverse tile (or equivalent) drains along the rock profile with headers and outlets shall be provided for drainage of seepage water and for relief of hydrostatic pressures that may develop due to saturation. The common arrangements for drainage of anchored training walls are illustrated in Fig. 11 and 12.

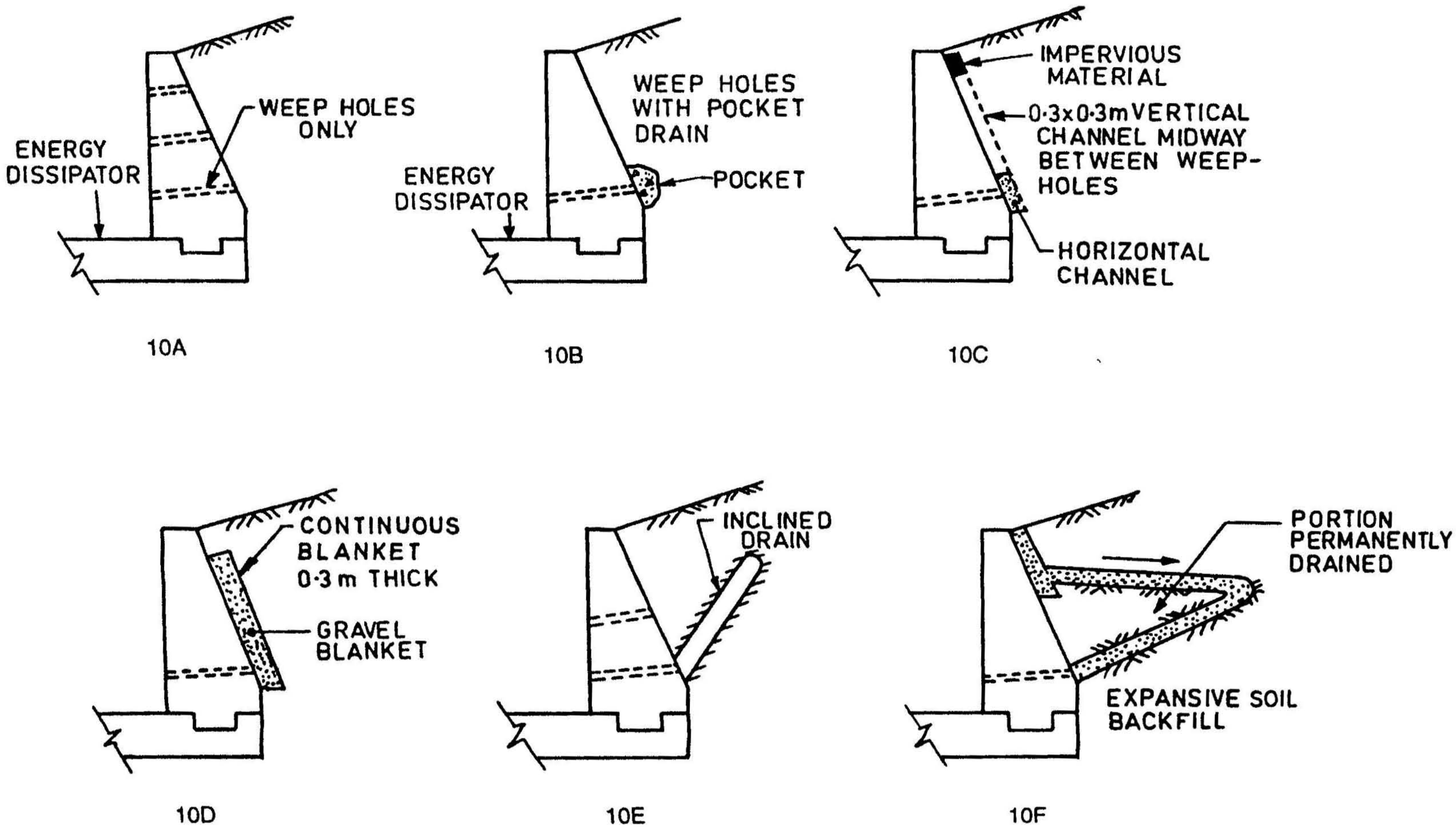
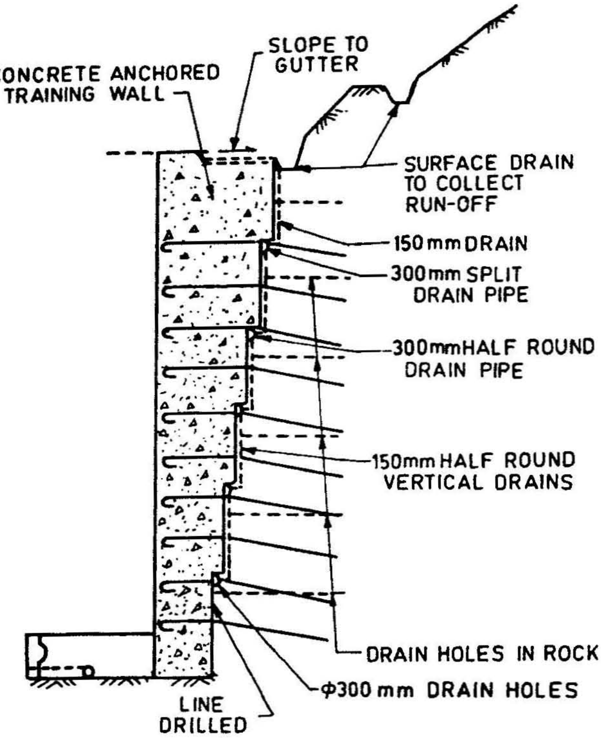


FIG. 10 TYPICAL BACKFULL DRAINS FOR GRAVITY TYPE TRAINING WALLLS OF ENERGY DISSIPATORS

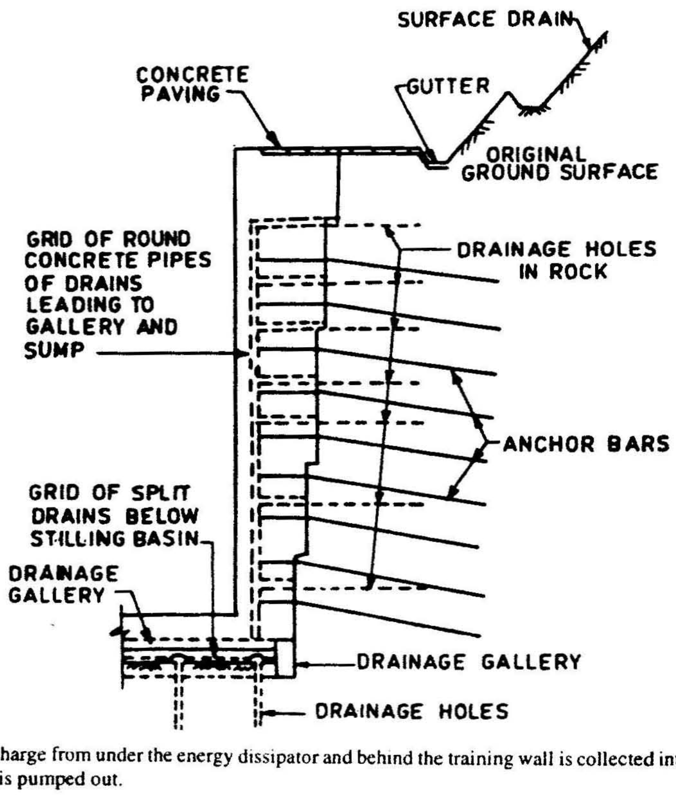


NOTES

1 Drain outlet shall be on similar lines as shown in Fig. 8B.

2 As an alternative, when outlets are provided to discharge into stilling basins/bucket, they may be provided with non-return valves.

FIG. 11 COMMON ARRANGEMENTS FOR DRAINAGE OF ANCHORED TRAINING WALLS



NOTE — The drain discharge from under the energy dissipator and behind the training wall is collected into the gallery and finally into the sump from where it is pumped out.

FIG. 12 ARRANGEMENTS FOR DRAINAGE OF ANCHORED TRAINING WALLS
(With Reference to **4.4**)

GMGIPN—147 BIS/ND/09-300

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones : 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.org.in

Regional Offices: *Telephones*

Central	: Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	2323 7617 2323 3841
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